

Broadening volcanic eruption forecasting using transfer machine learning.

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Martin Letourneur¹

Shane Cronin²

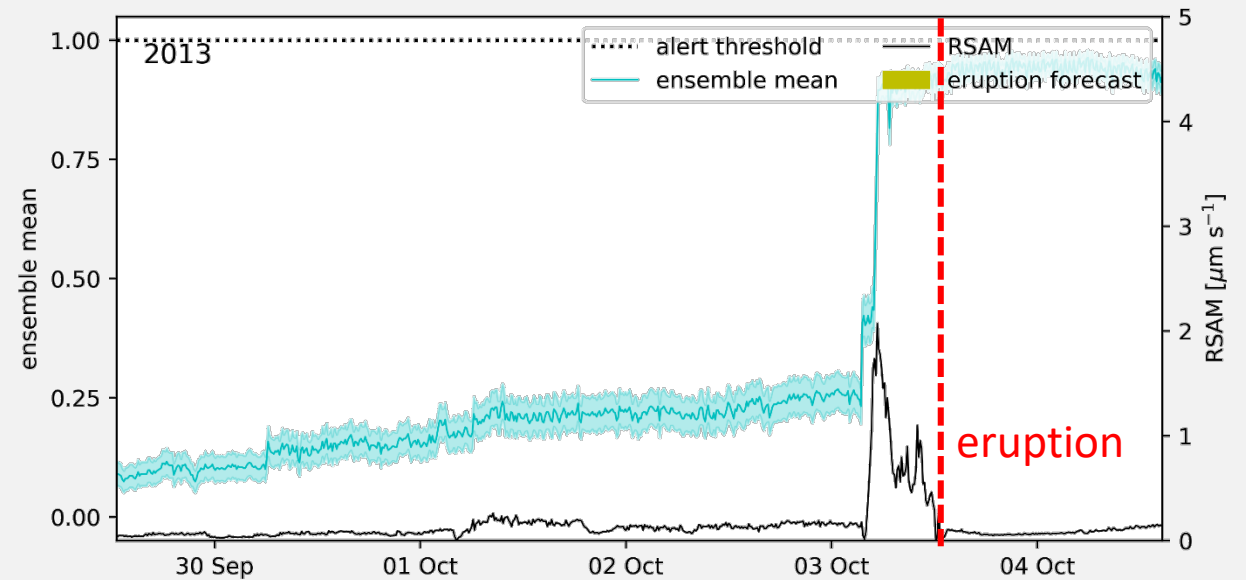
Andreas Kempa-Liehr²

¹University of Canterbury

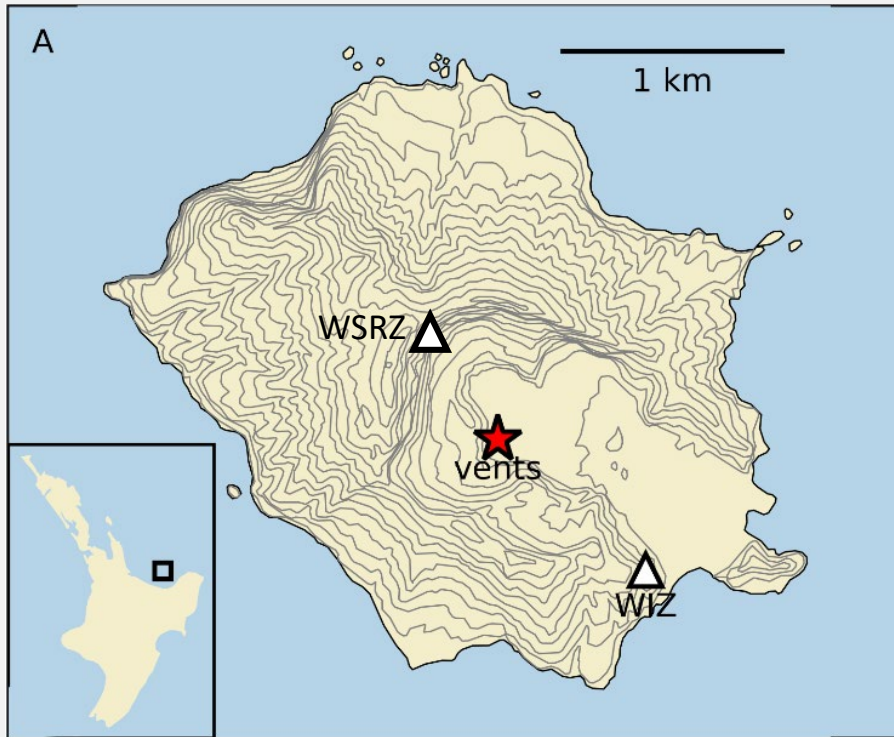
²University of Auckland
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[@DavidEDempsey](https://twitter.com/DavidEDempsey)



On 9 Dec 2019, Whakaari (White Island) erupted suddenly, killing 21 people. It was the 5th eruption in ten years.



[still footage provided to thespinooff.co.nz]

At present, a **Volcano Alert Level** (VAL) is determined through expert consensus. This could be complemented with real-time forecasting.

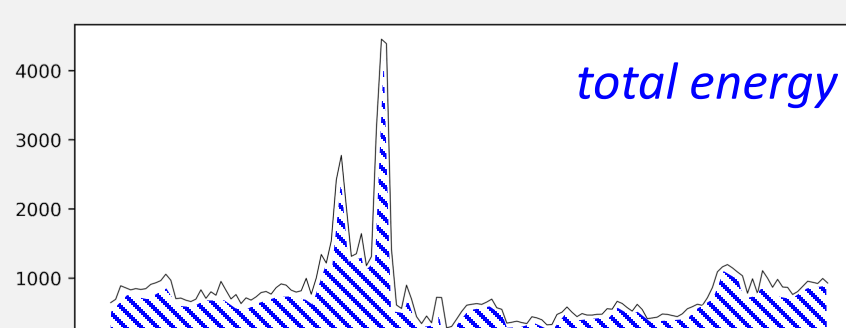
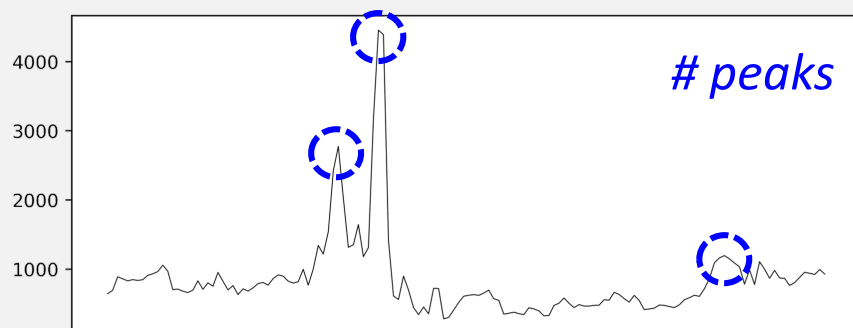
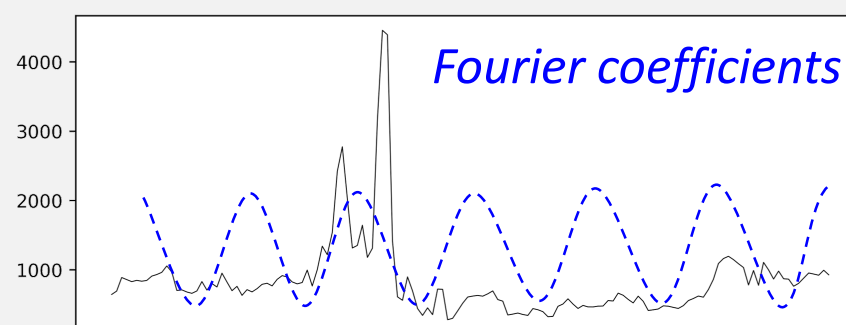
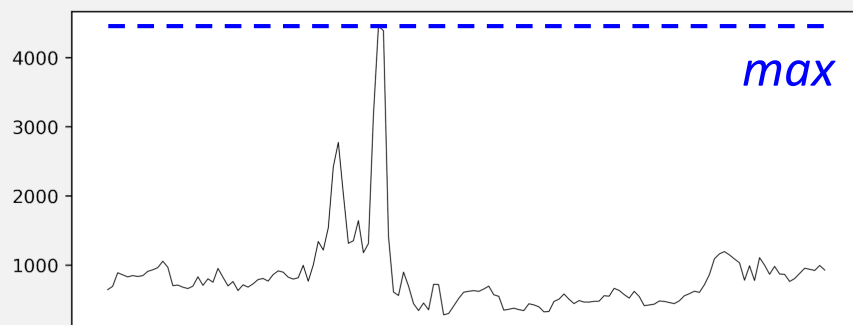
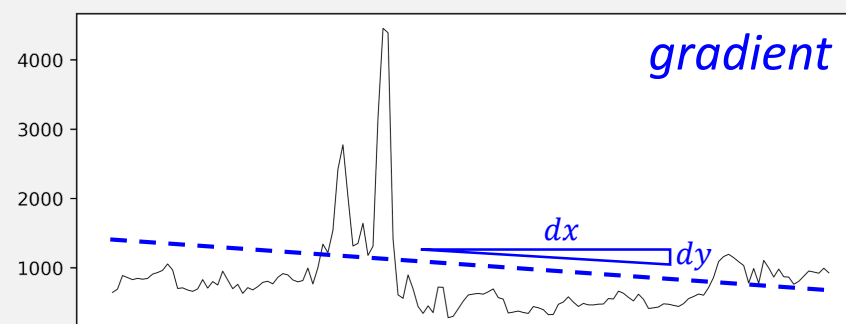
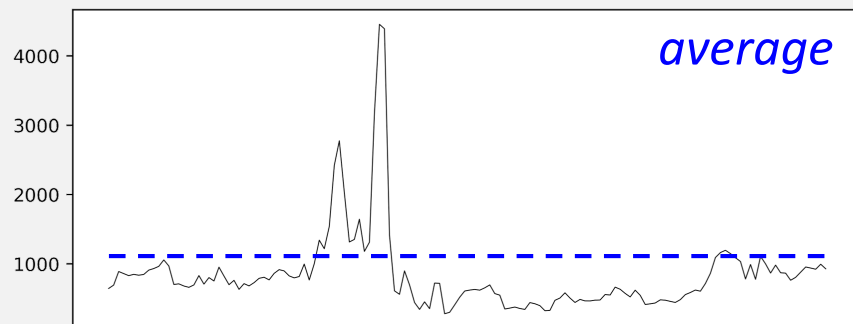
Whakaari was at
VAL 2 before
2019 eruption.



New Zealand Volcanic Alert Level System			
		Volcanic Alert Level	Most Likely Hazards
Eruption	5	Major volcanic eruption	Eruption hazards on and beyond volcano*
	4	Moderate volcanic eruption	Eruption hazards on and near volcano*
	3	Minor volcanic eruption	Eruption hazards near vent*
Unrest	2	Moderate to heightened volcanic unrest	Volcanic unrest hazards, potential for eruption hazards
	1	Minor volcanic unrest	Volcanic unrest hazards
	0	No volcanic unrest	Volcanic environment hazards

[Potter et al., JAV, 2014]

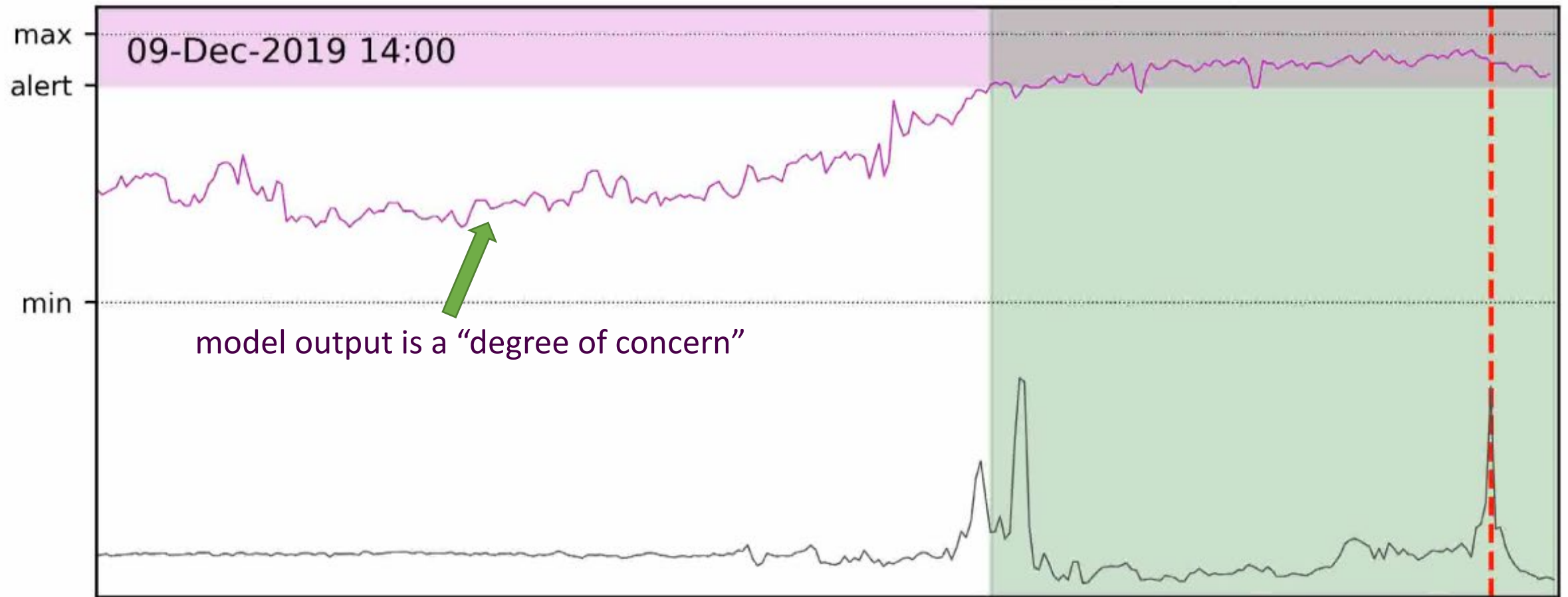
We developed a short-term alert system that picks 4 out of 5 eruptions with good accuracy.



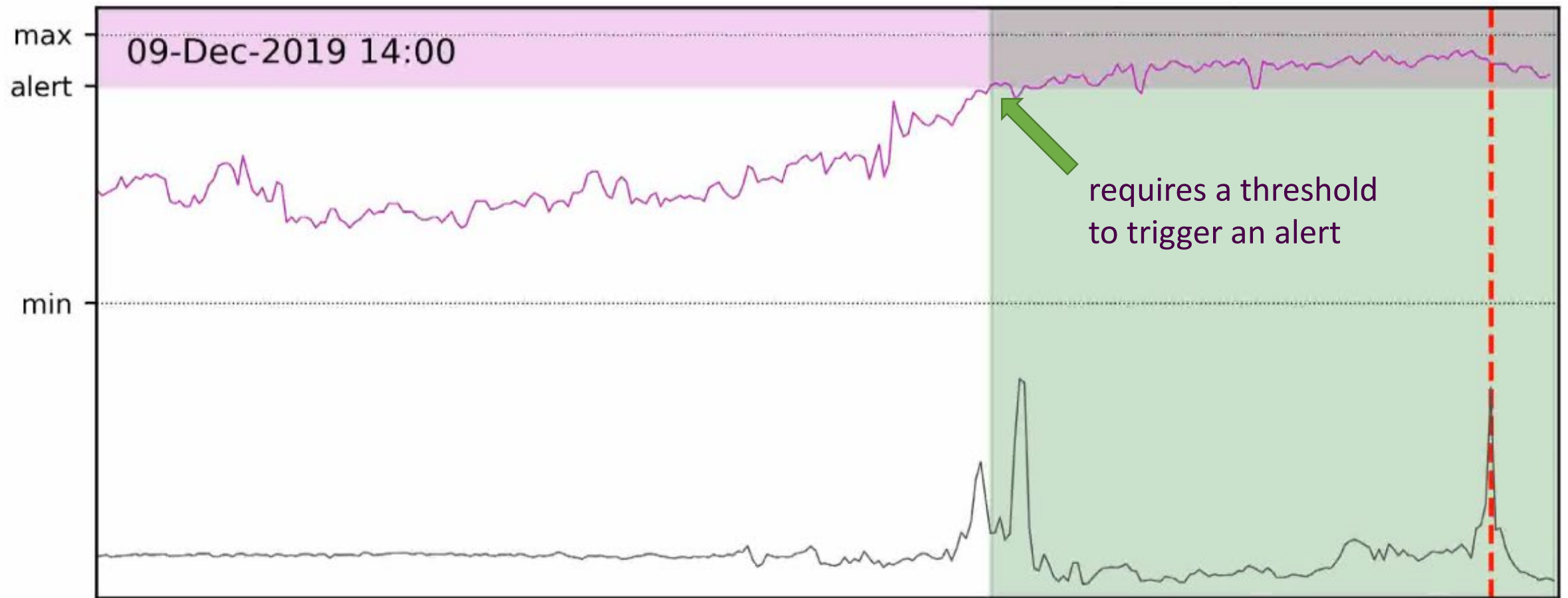
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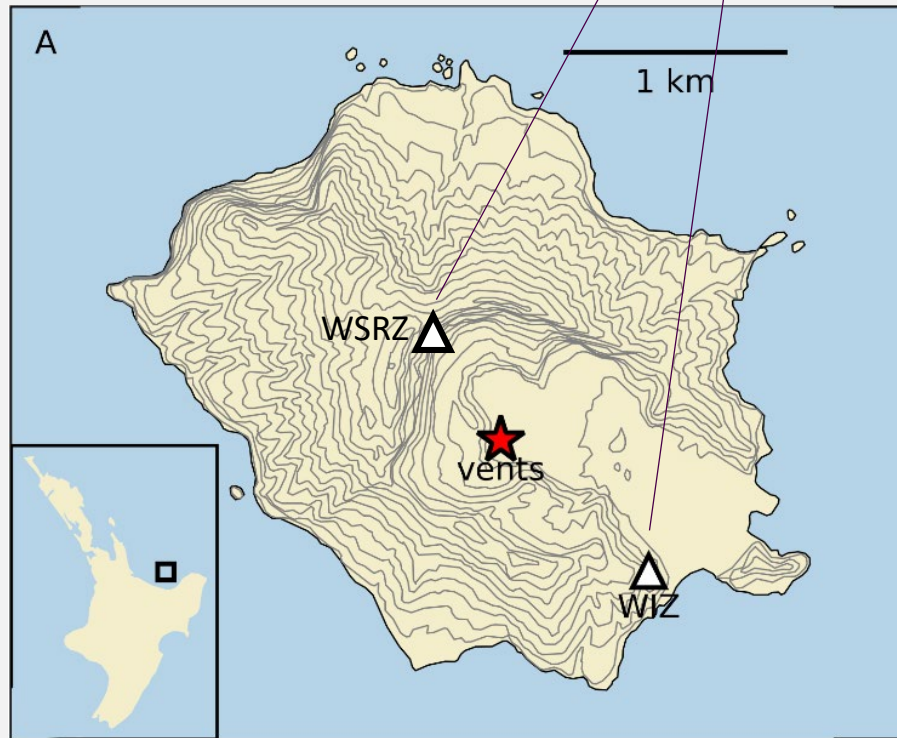
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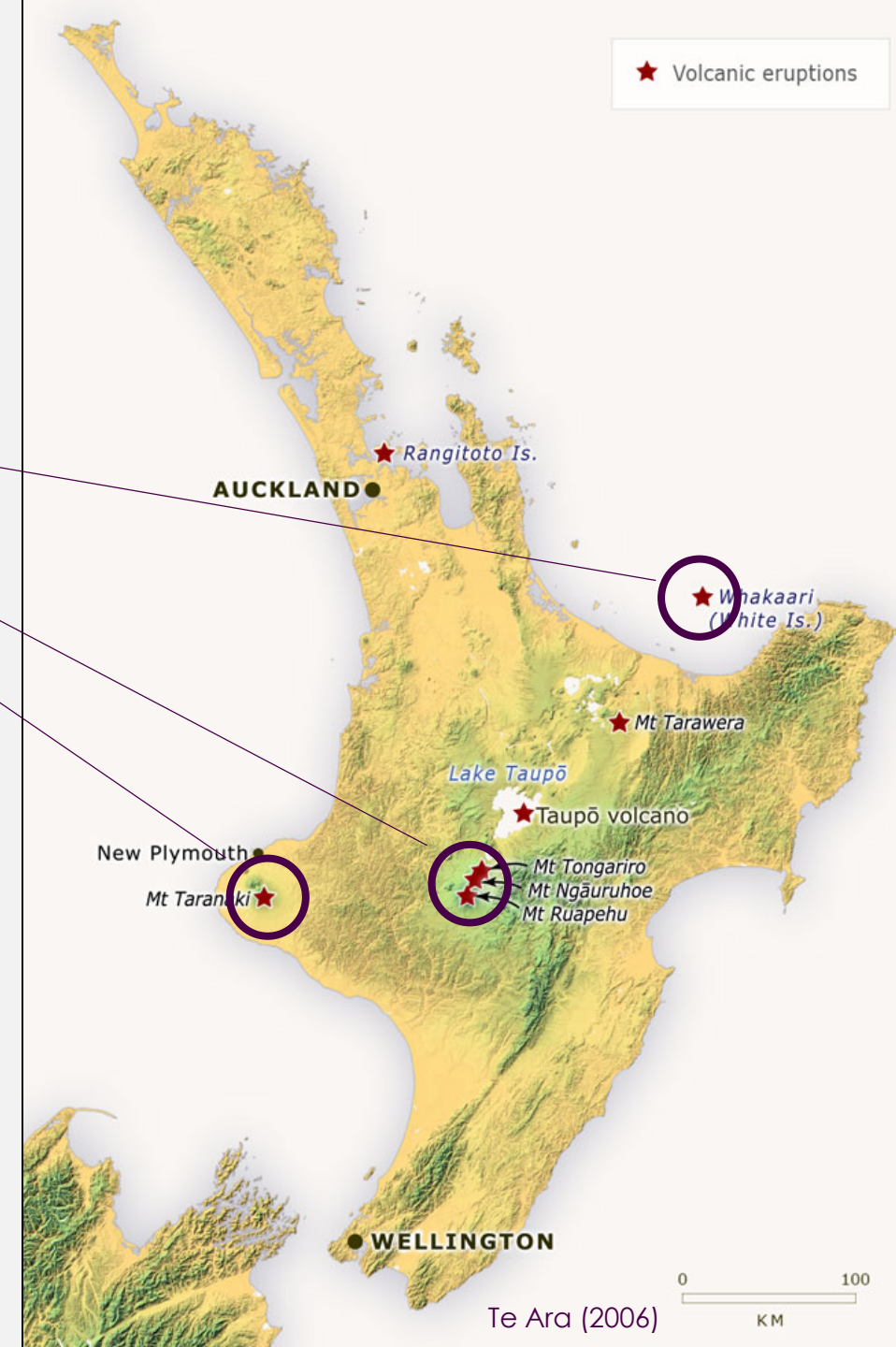
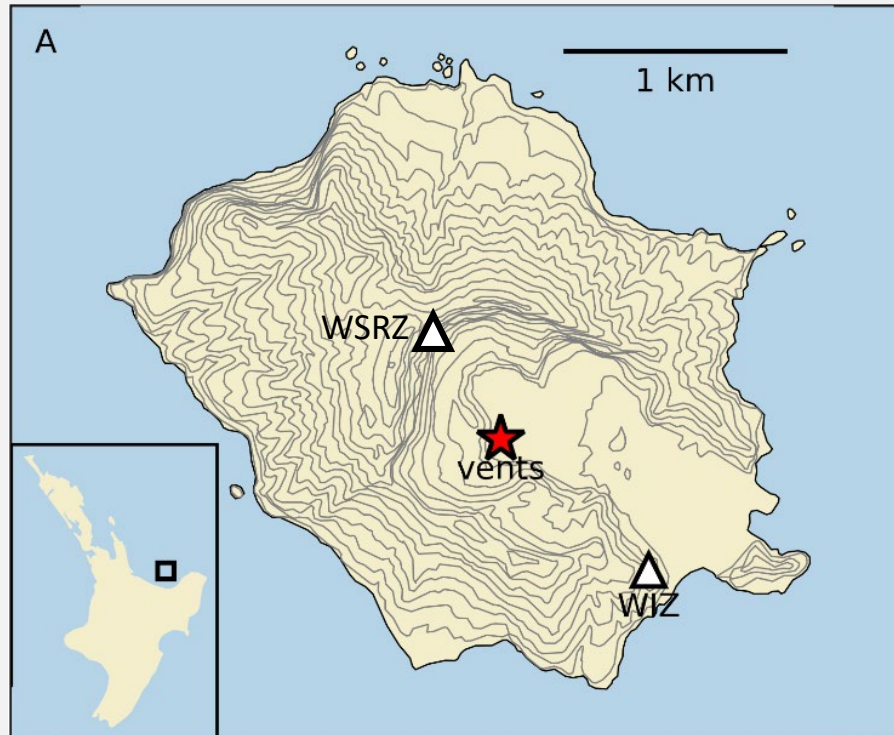
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Goal: broaden forecasting
ability to other seismometers



Goal: broaden forecasting ability to other seismometers and other volcanoes.



1. The **missing data** problem. Records at WIZ and WSRZ have gaps.

2. The **data comparison** problem. WIZ and WSRZ record the same(ish) signal, but at different amplitudes.

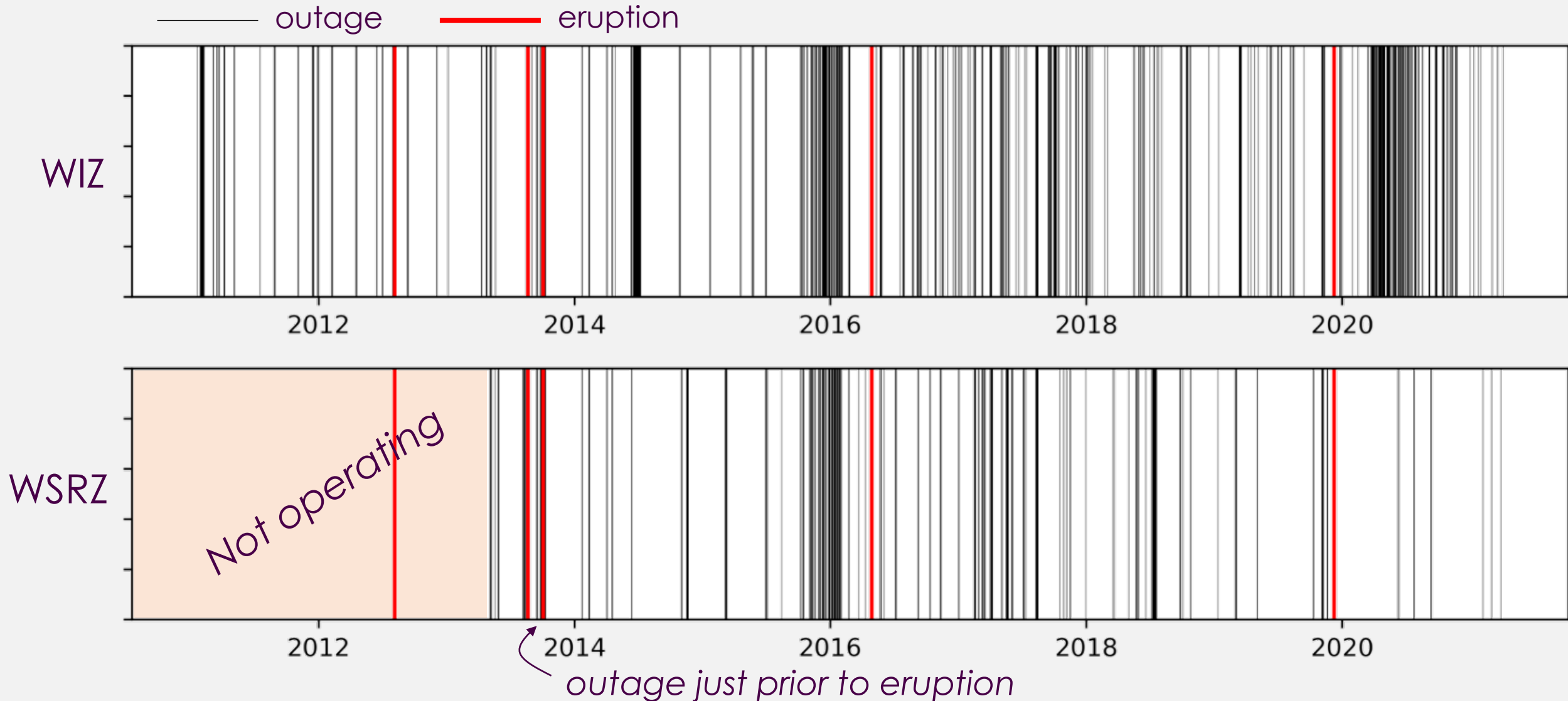
3. The **generalisation** problem. Ruapehu has fewer recorded eruptions – what can be transferred from the Whakaari forecaster?

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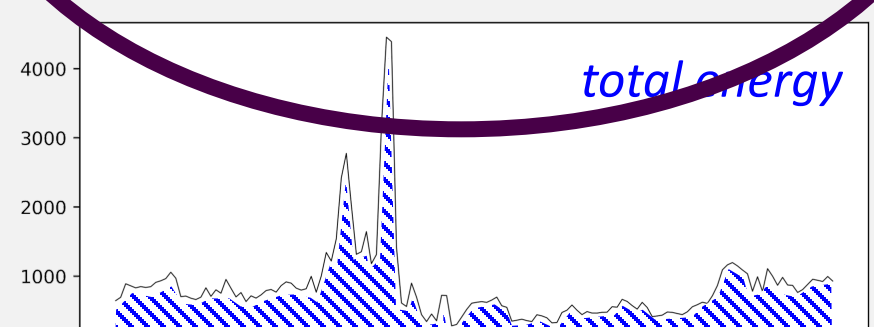
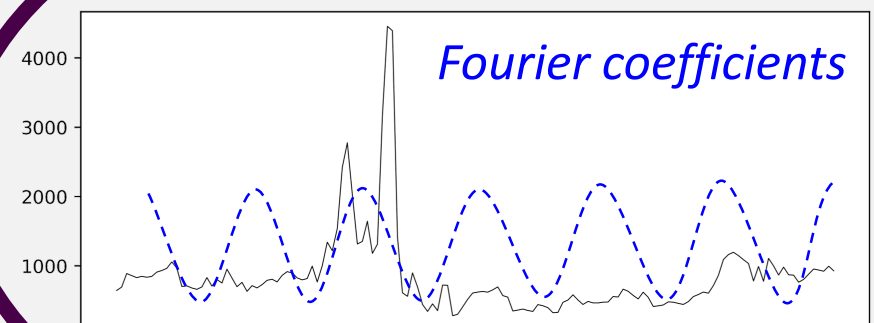
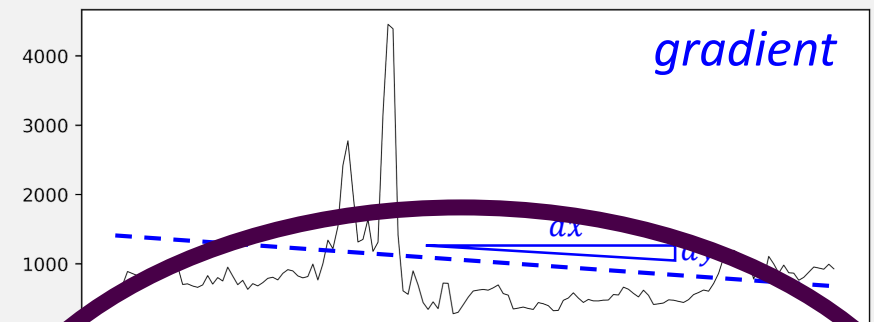
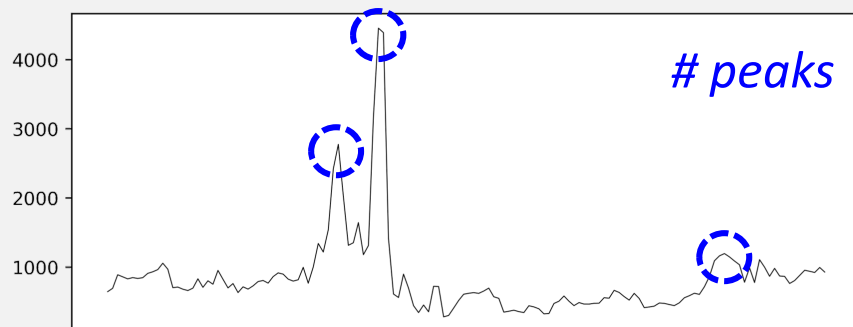
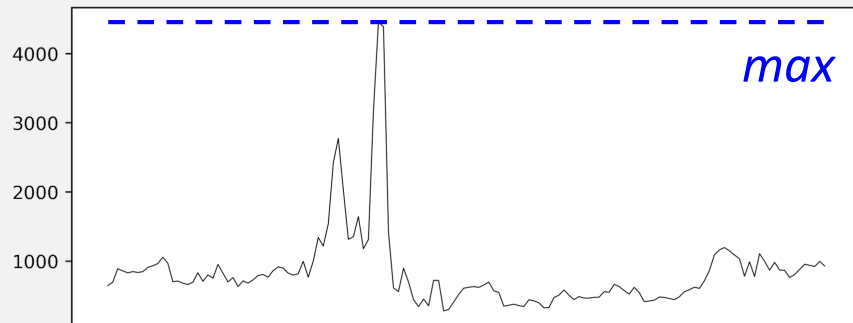
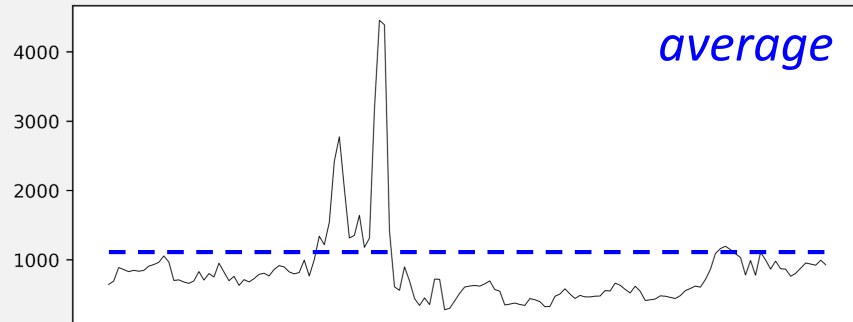
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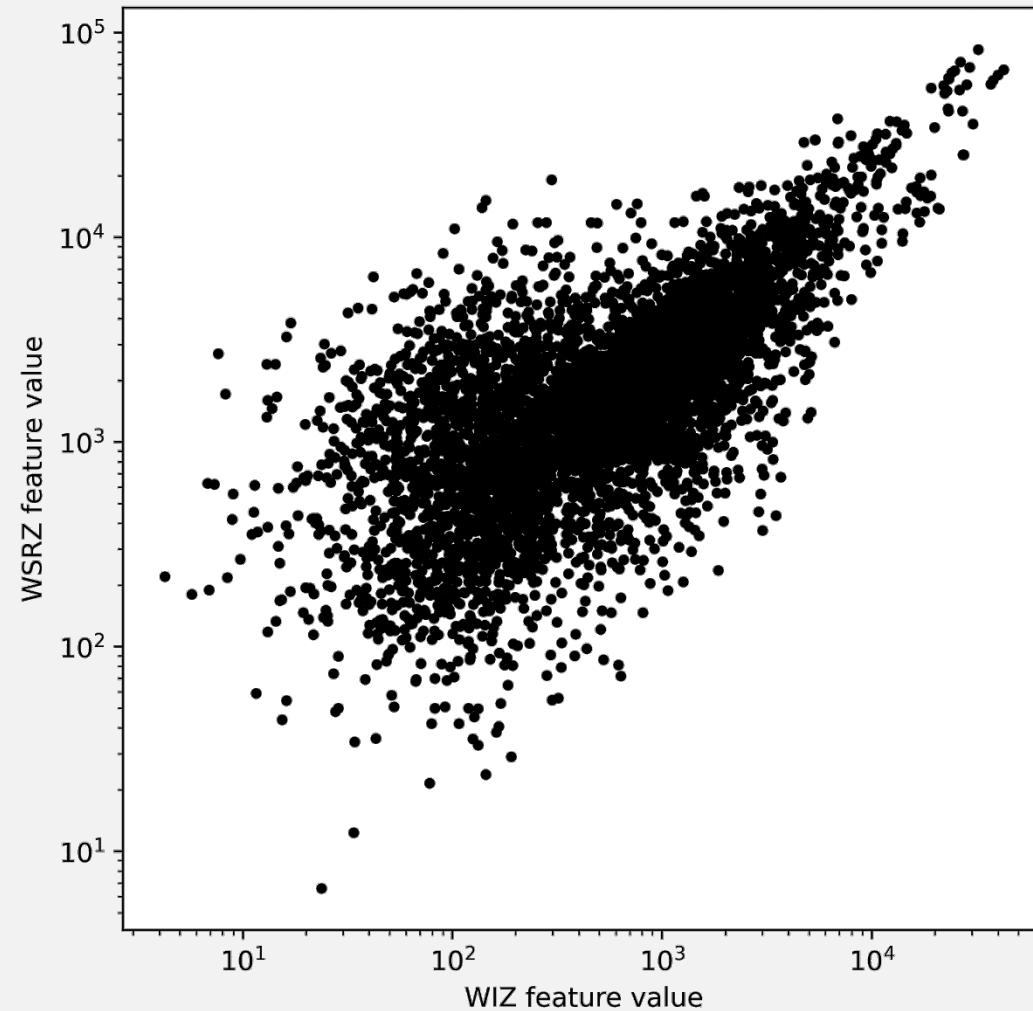
WSRZ not operating during 2012 eruption and had outages before Oct 2013 eruption.



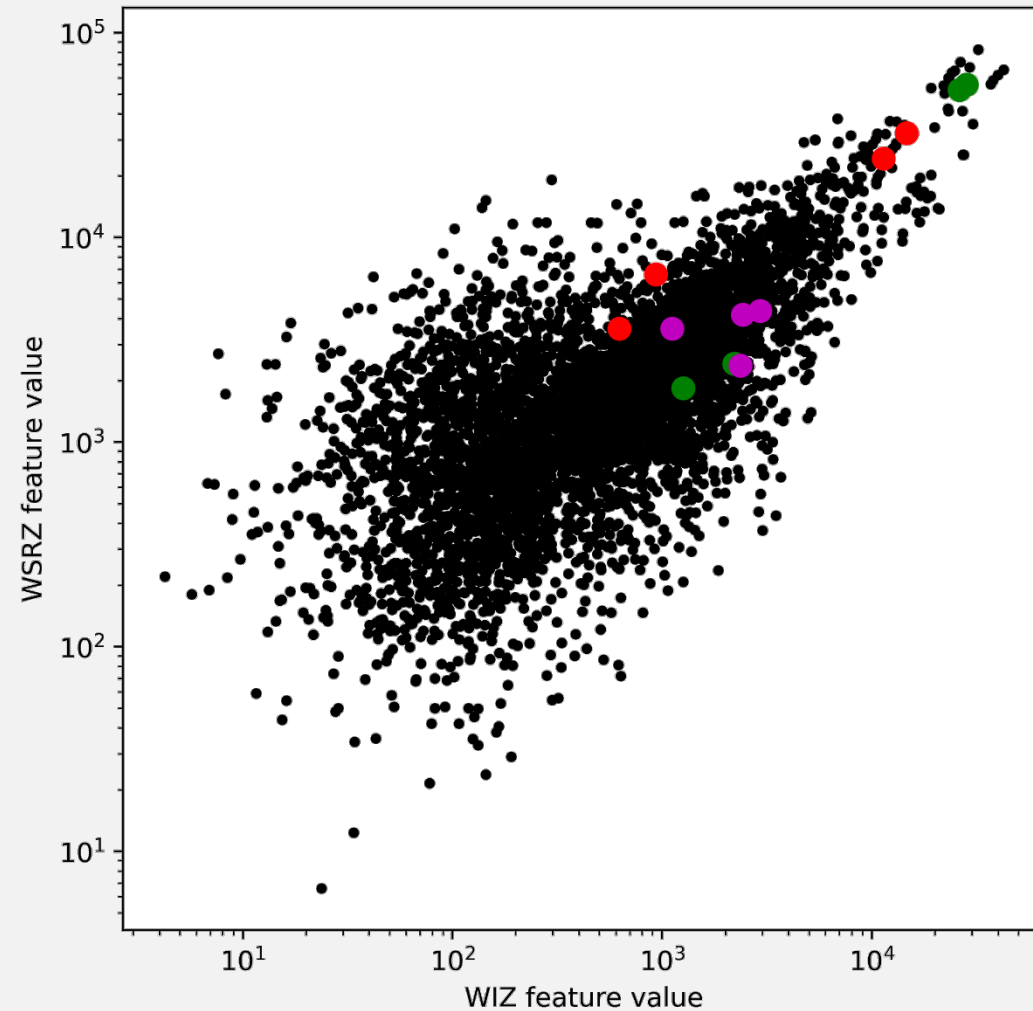
Gap-filling: regression of concurrent pre-eruption features then stochastic interpolation.



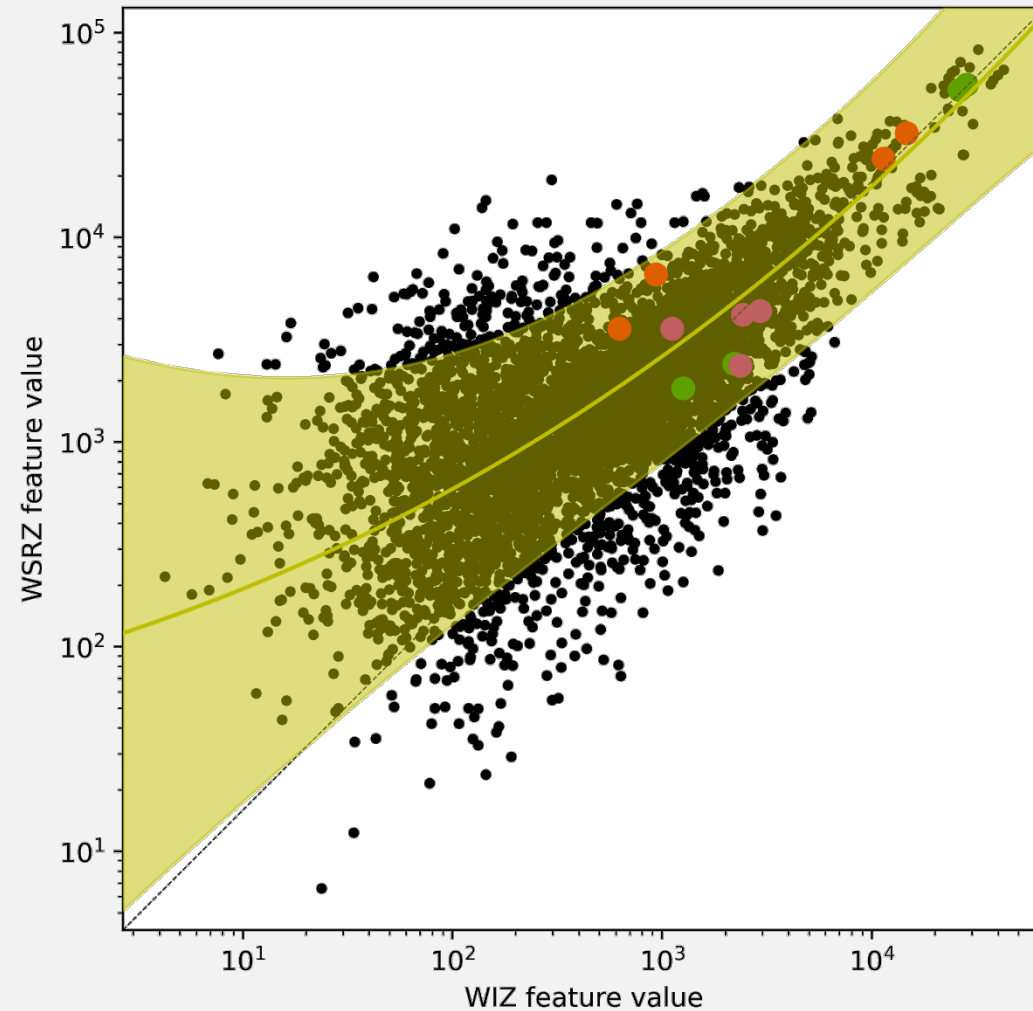
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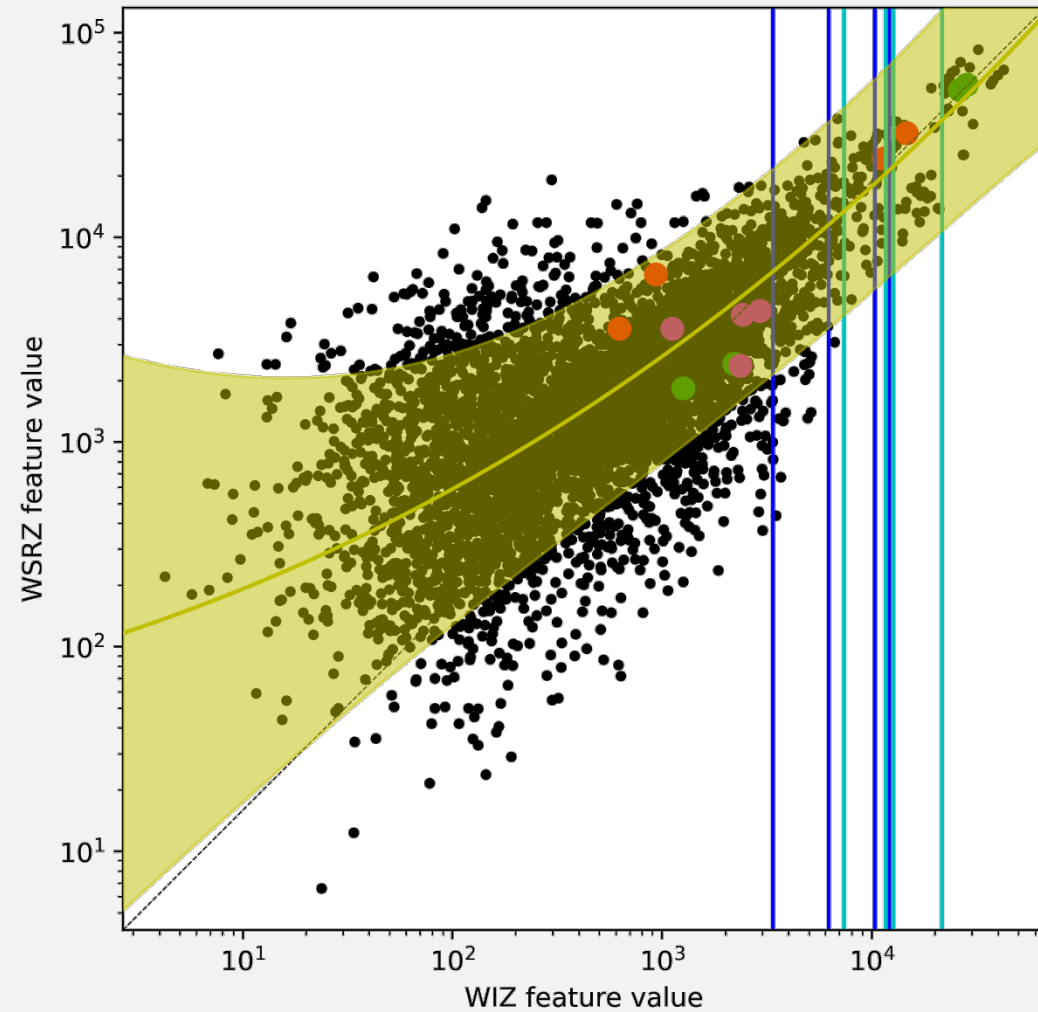
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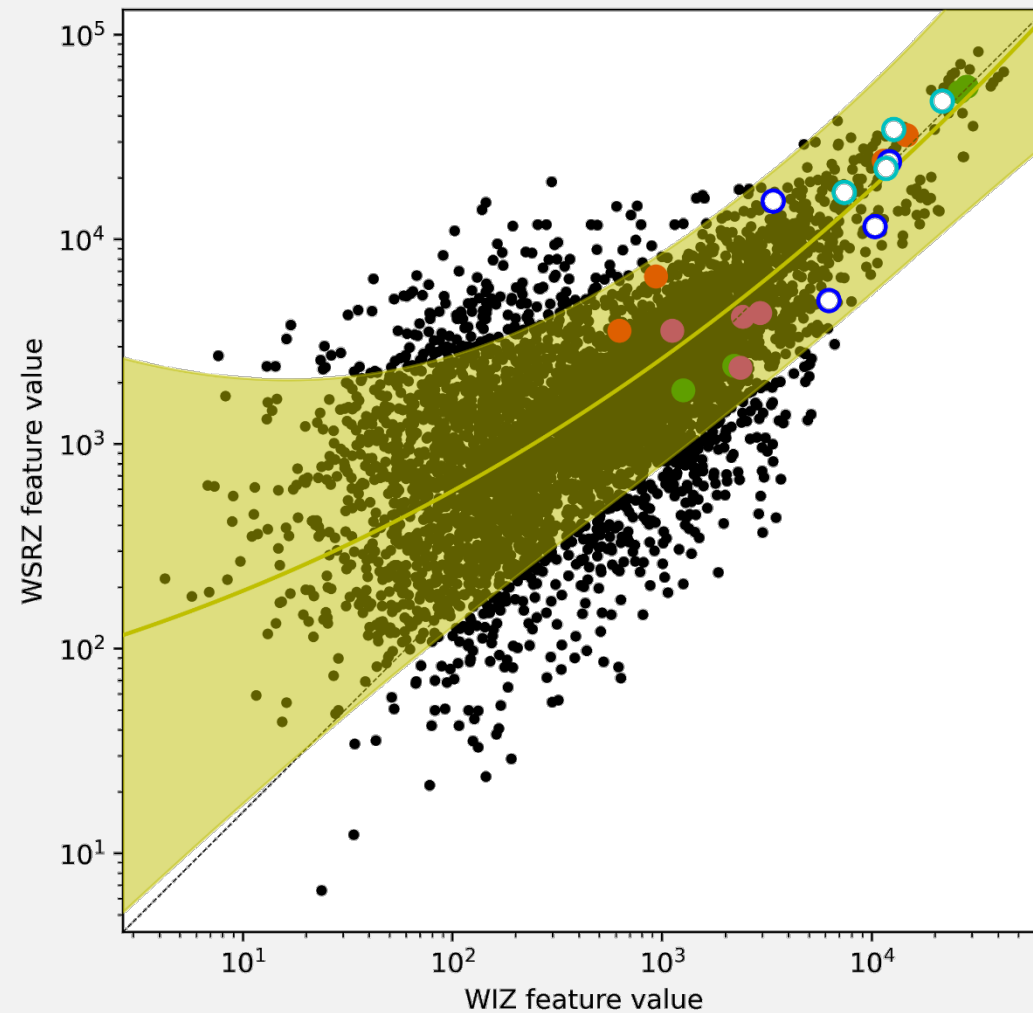
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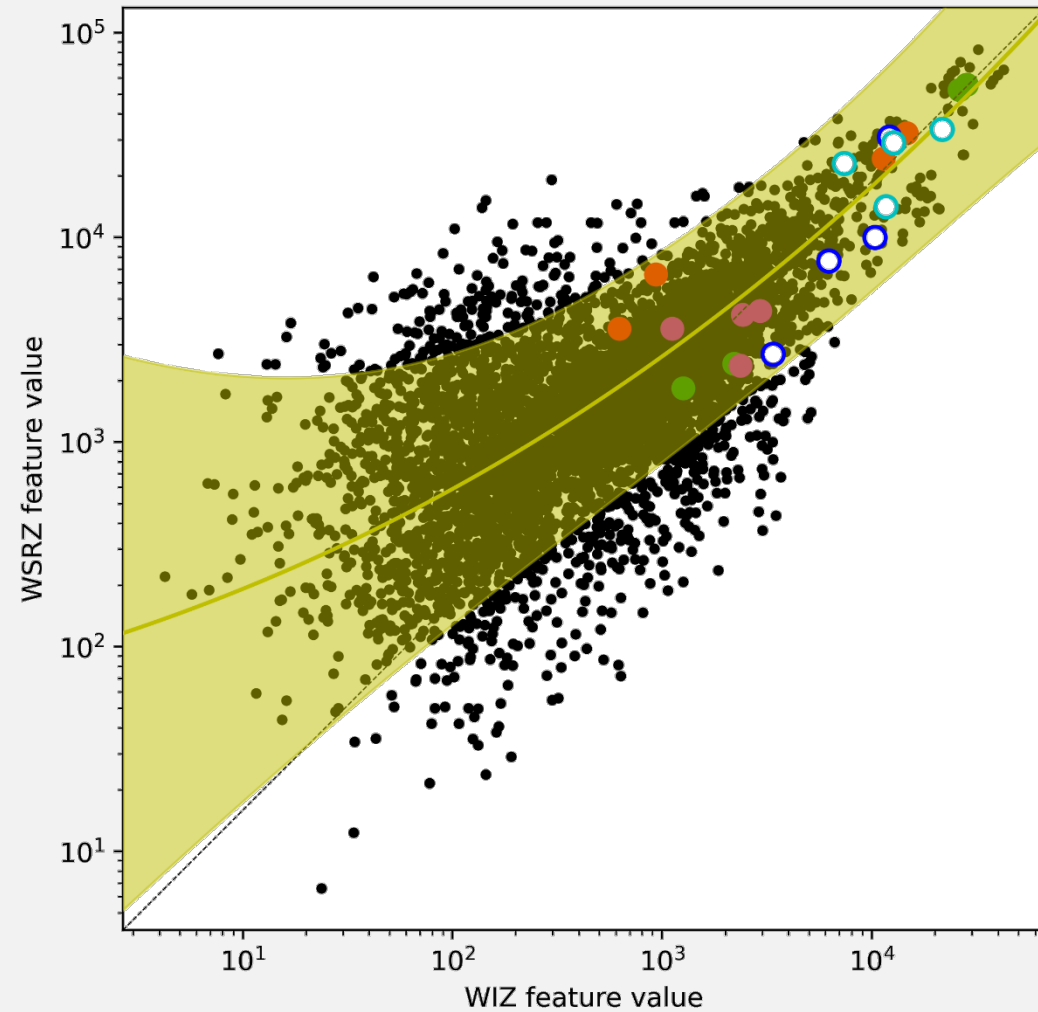
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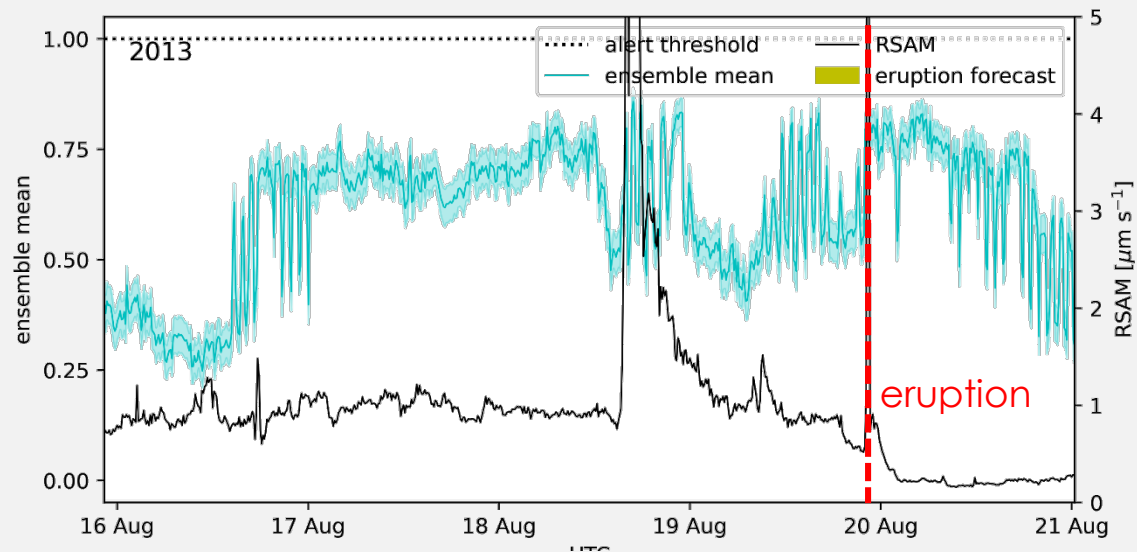
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Gap-filling: regression of concurrent pre-eruption features then **stochastic** interpolation.

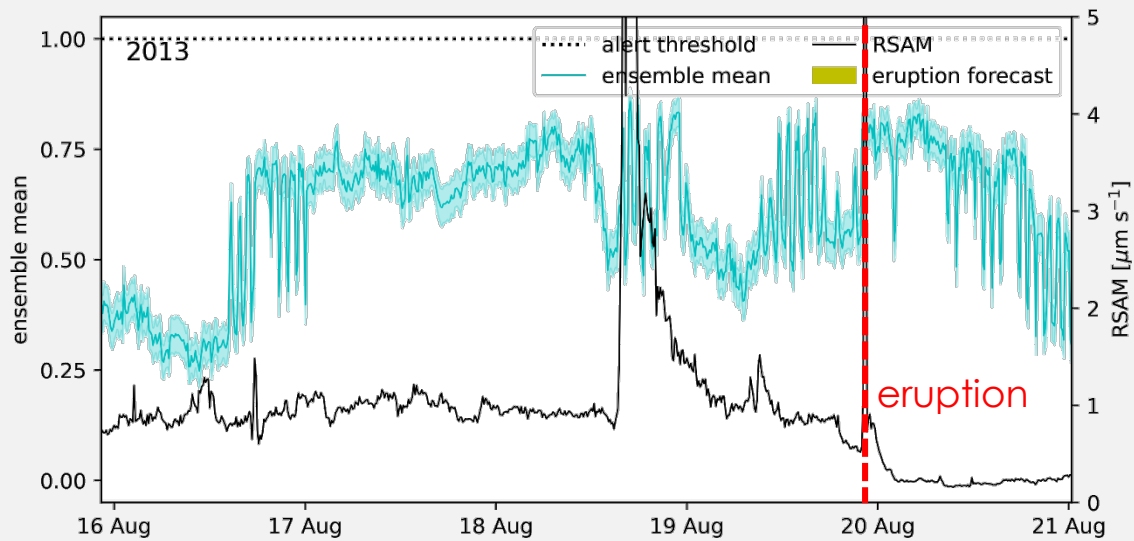


A WSRZ forecast model trained using gap-filling performs about as well as the WIZ model trained on all the data.

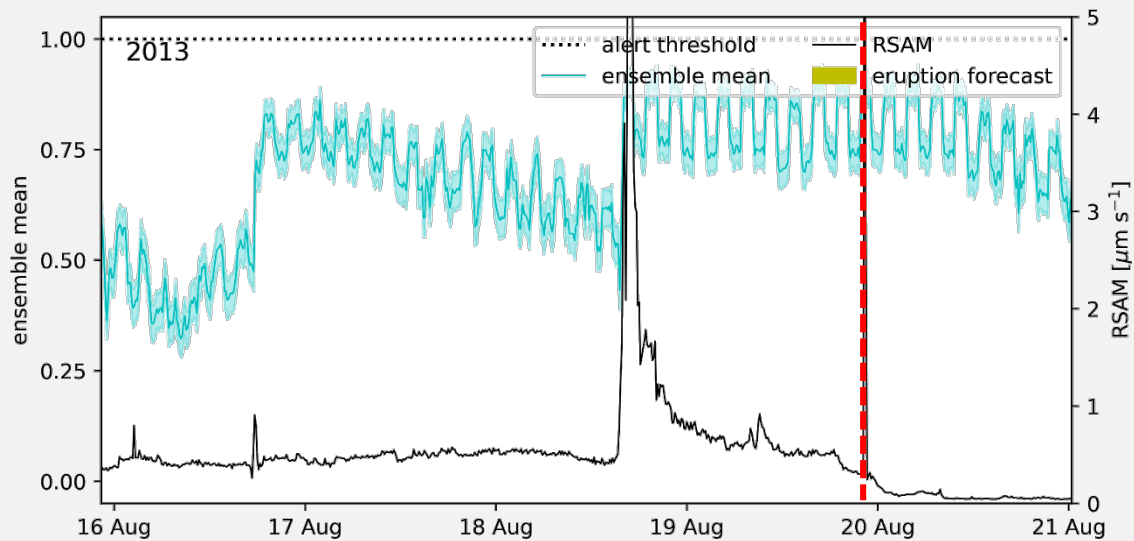


← WSRZ with gap-fill
Best score: 0.83

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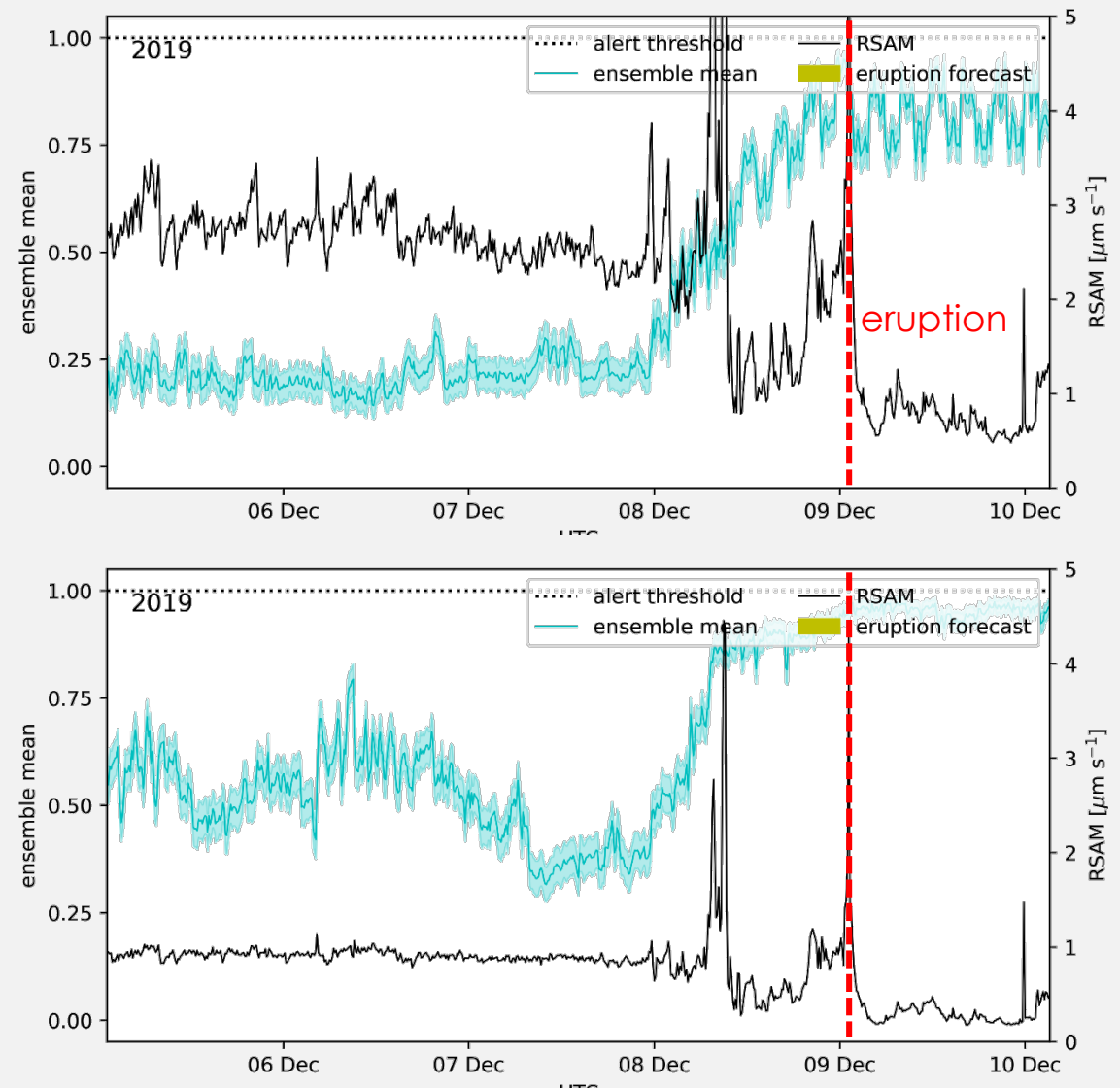


← original WIZ
Best score: 0.9

A WSRZ forecast model trained using gap-filling performs about as well as the WIZ model trained on all the data.

WSRZ with gap-fill →
Best score: 0.94

original WIZ →
Best score: 0.94

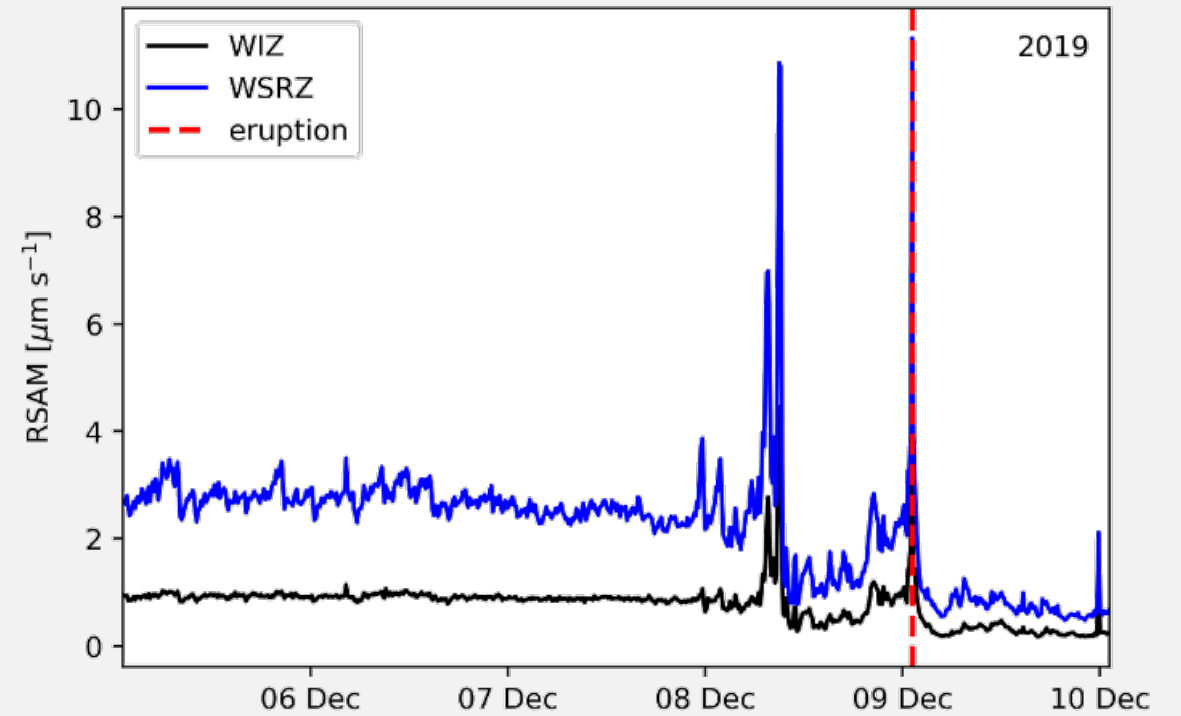
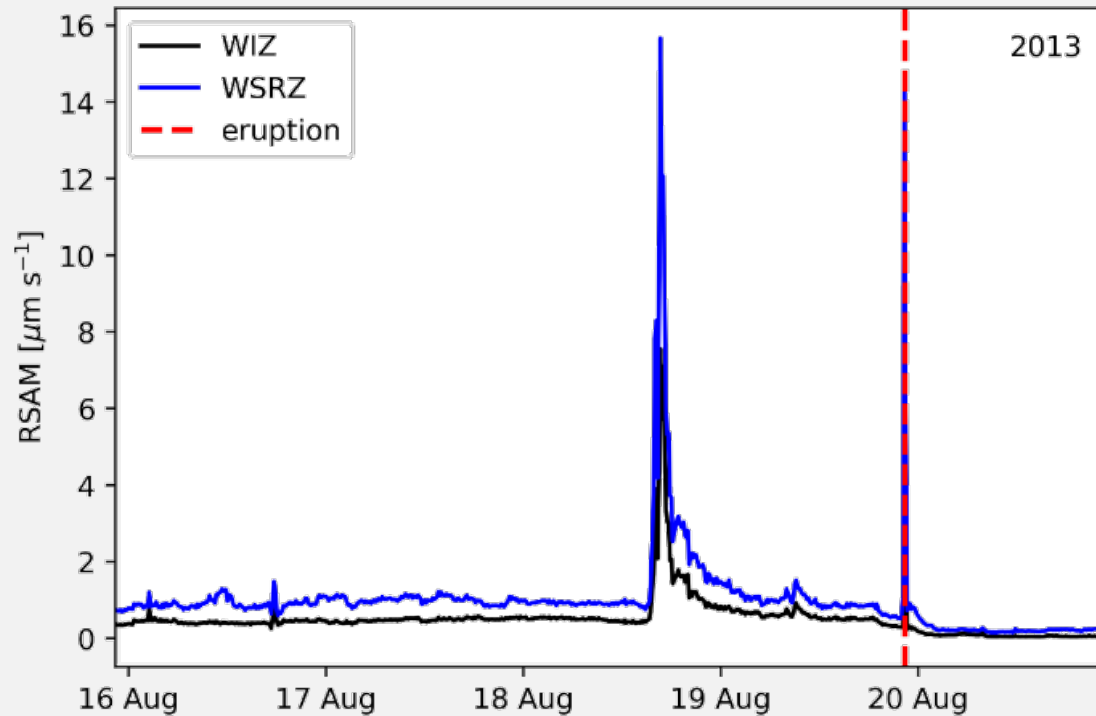


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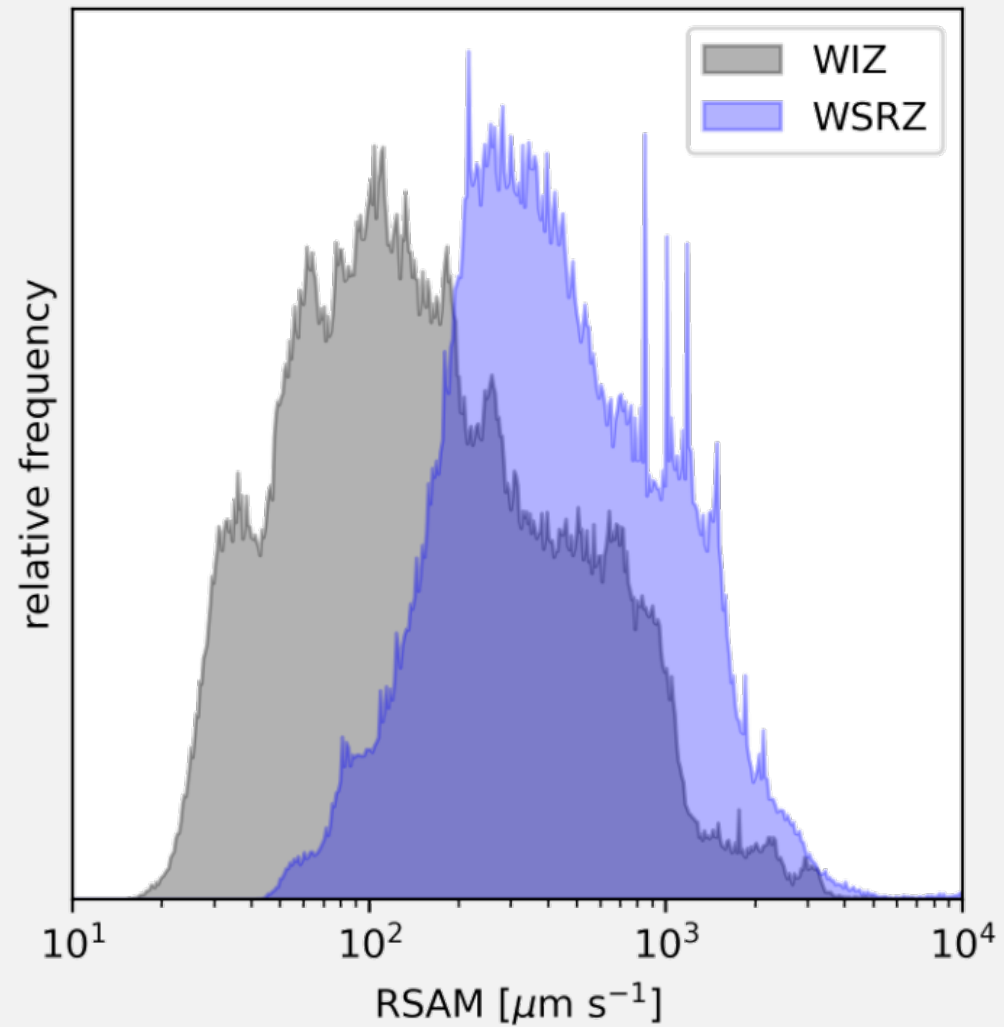
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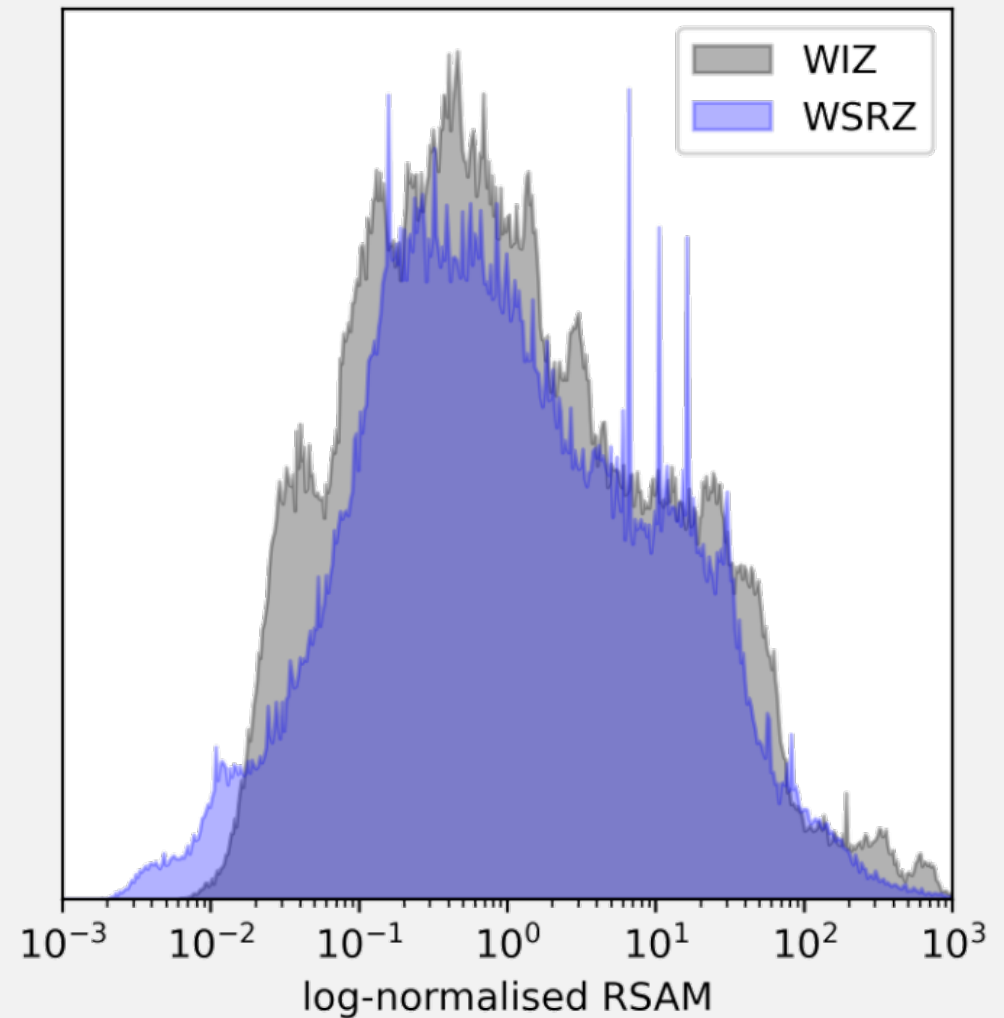
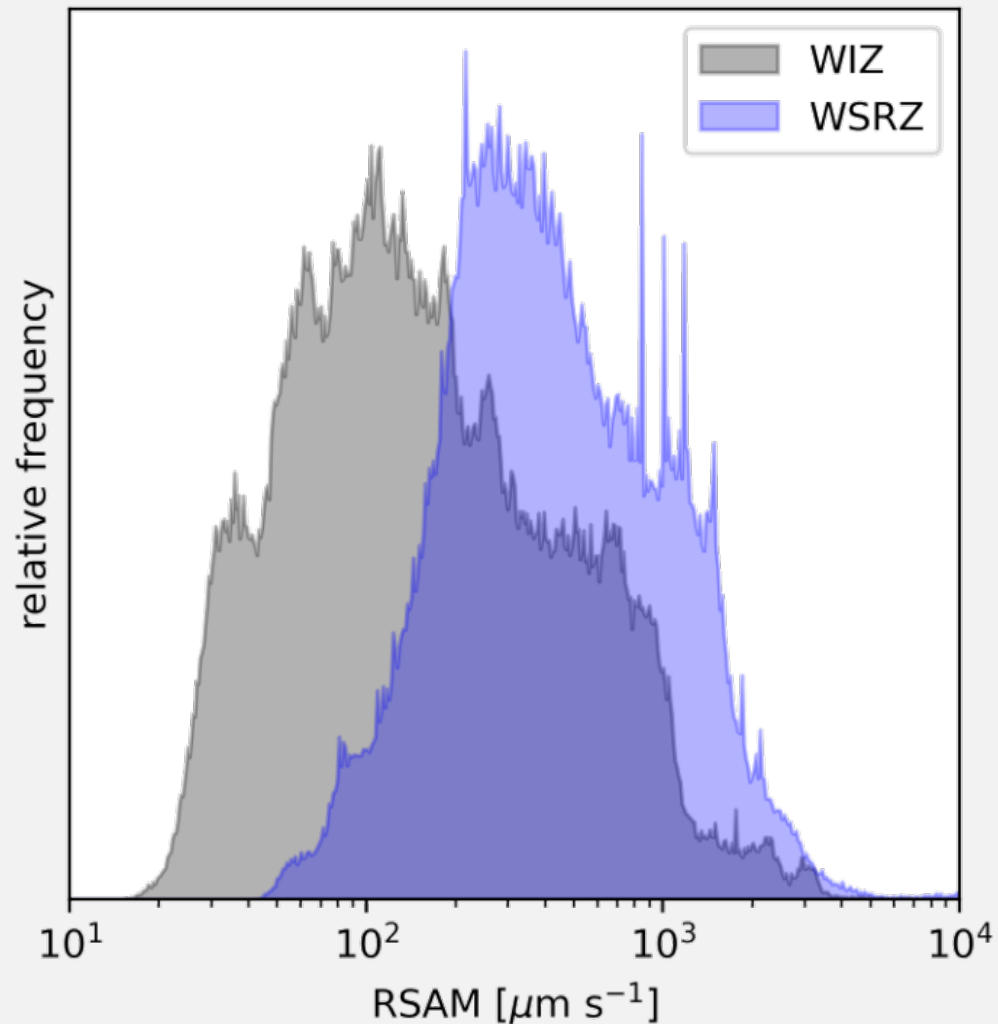
It would be better if there were some **universal standard** that signals could be transformed back to.



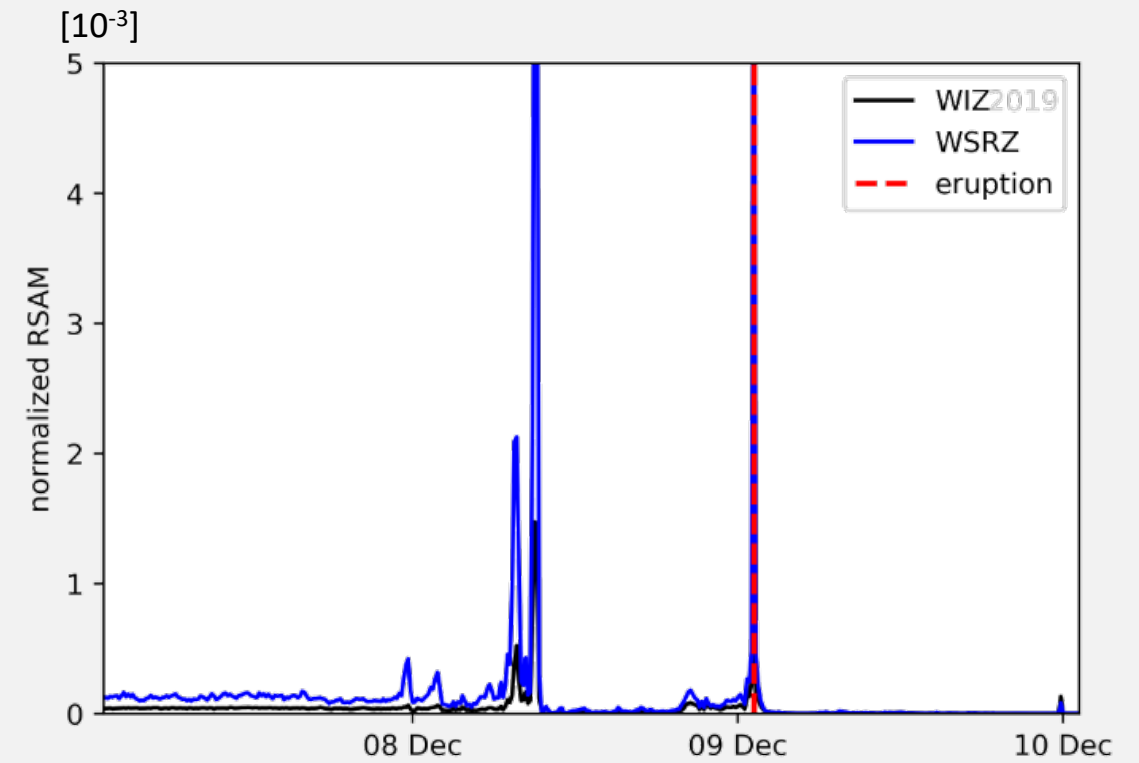
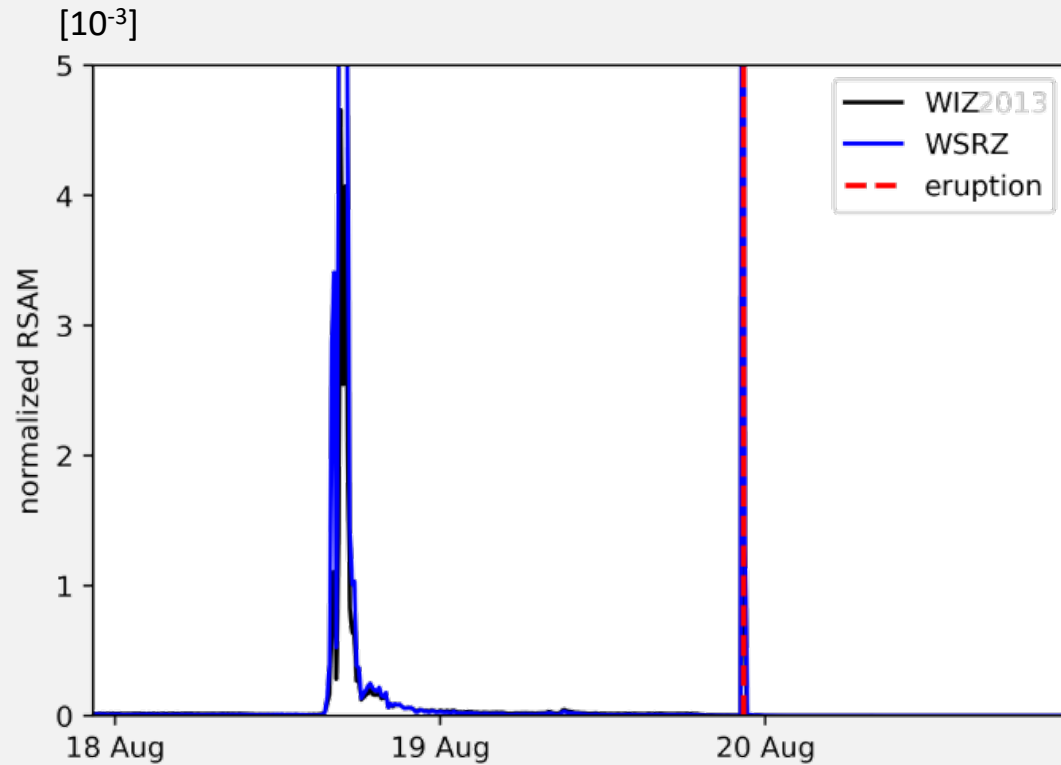
The raw data are *somewhat* log-normally distributed



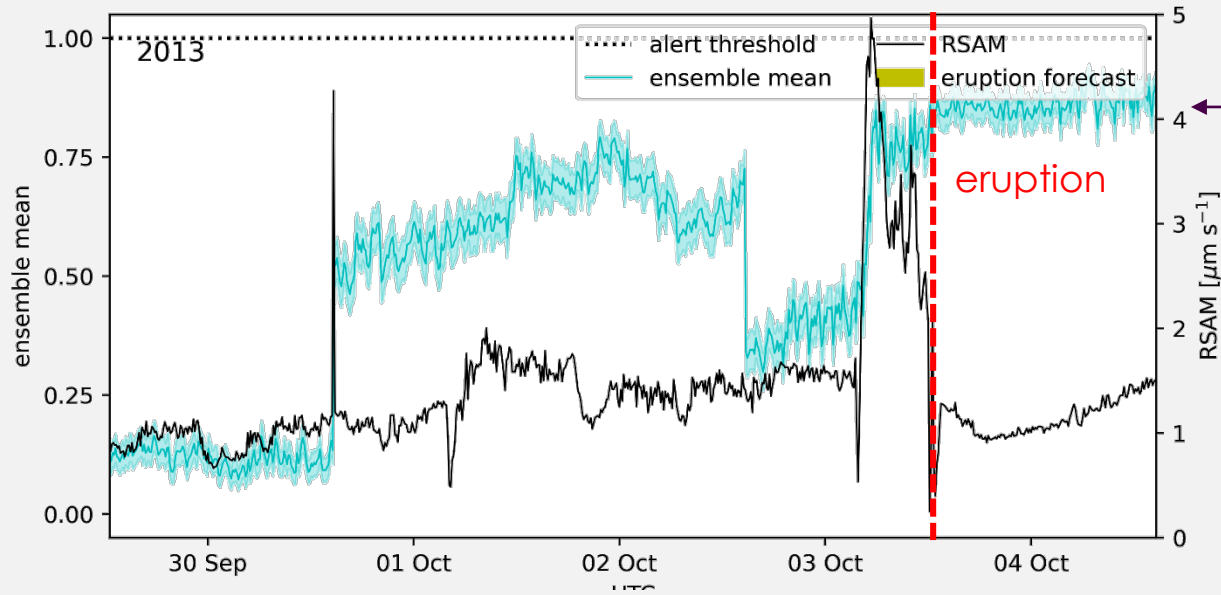
The raw data are *somewhat* log-normally distributed, so we used a **log unit-normal transformation**.



The result is improved (if still imperfect) overlap between the signals.

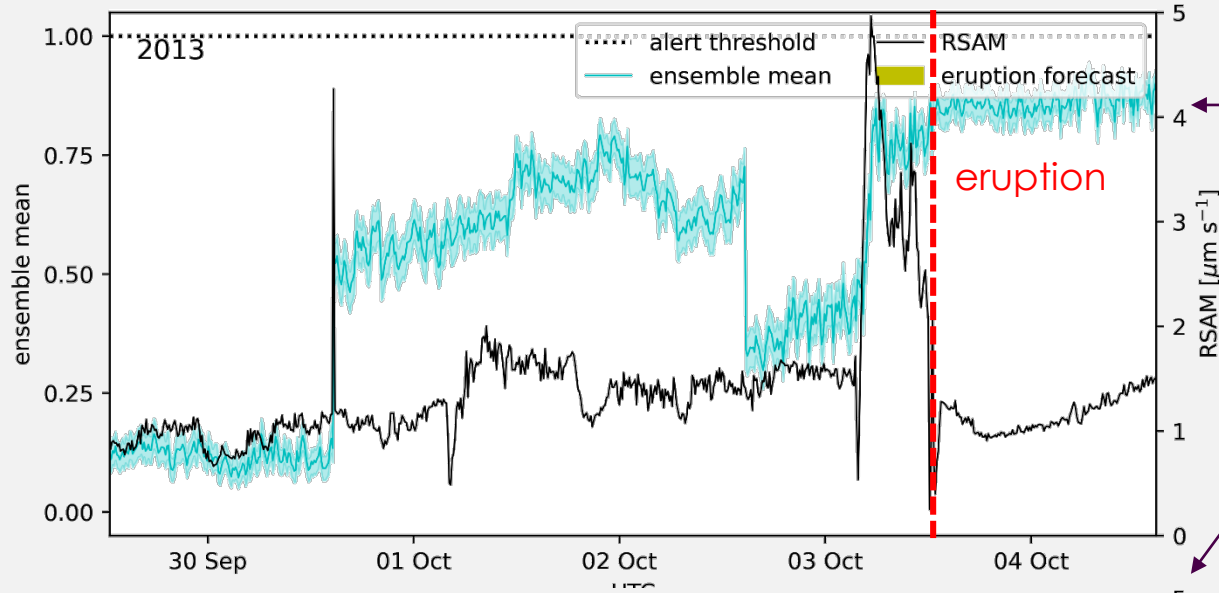


Models trained on standardized signals perform about as well on the out-of-sample eruptions used for testing.

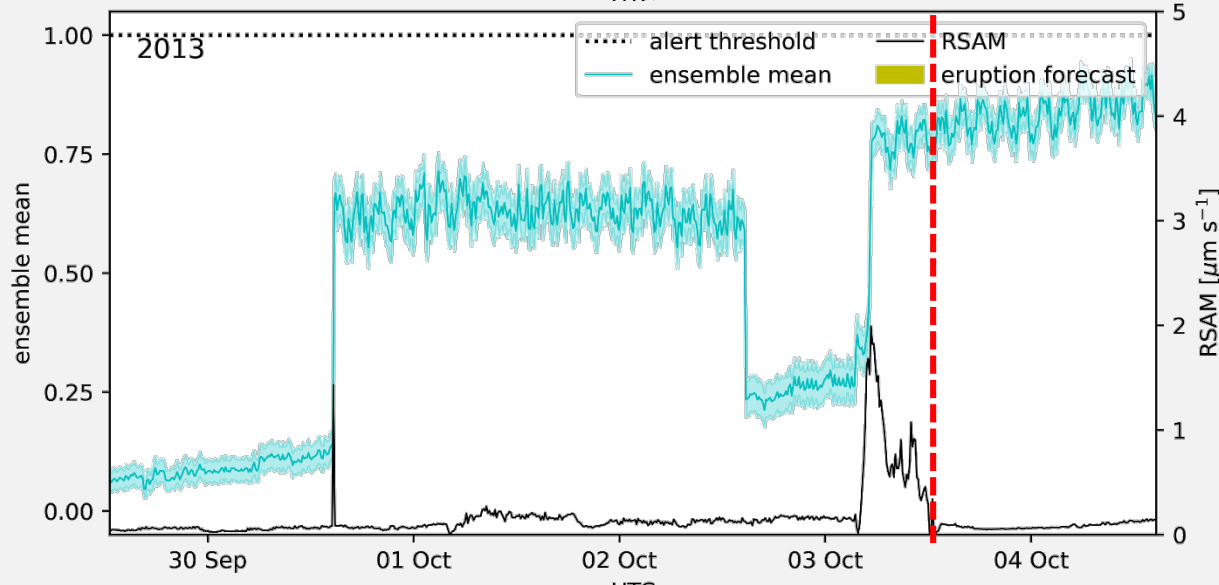


original forecast

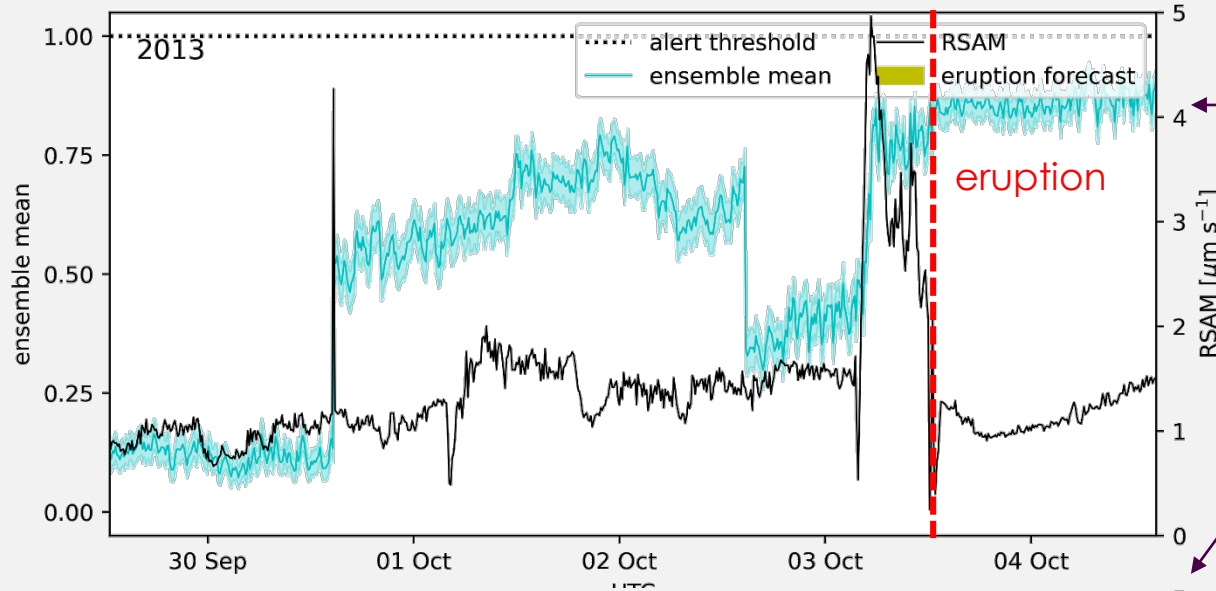
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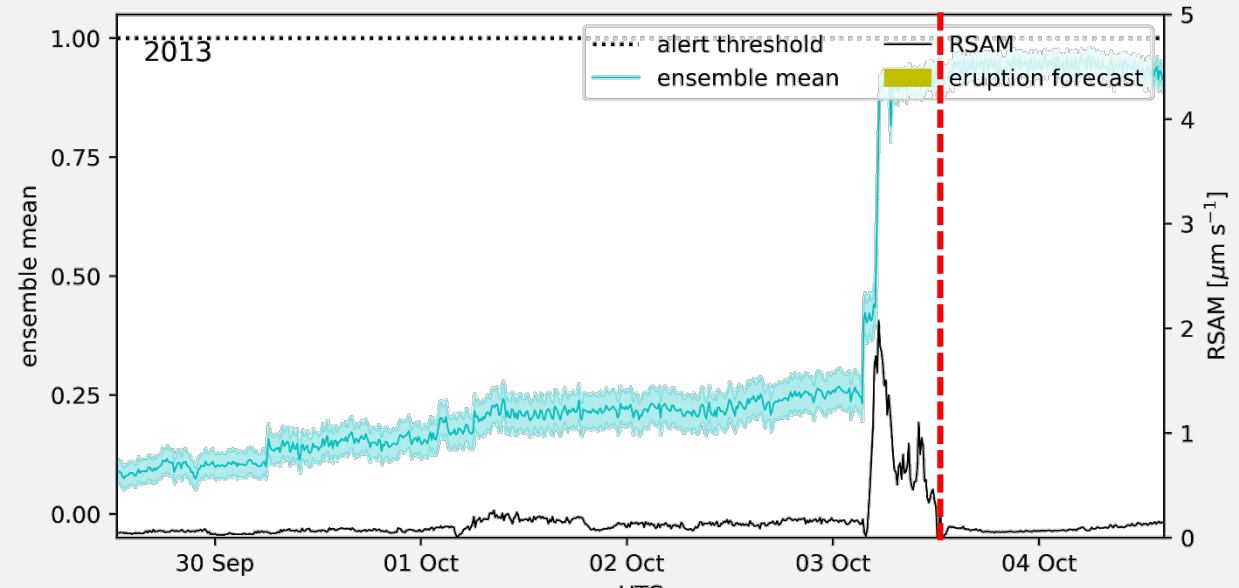
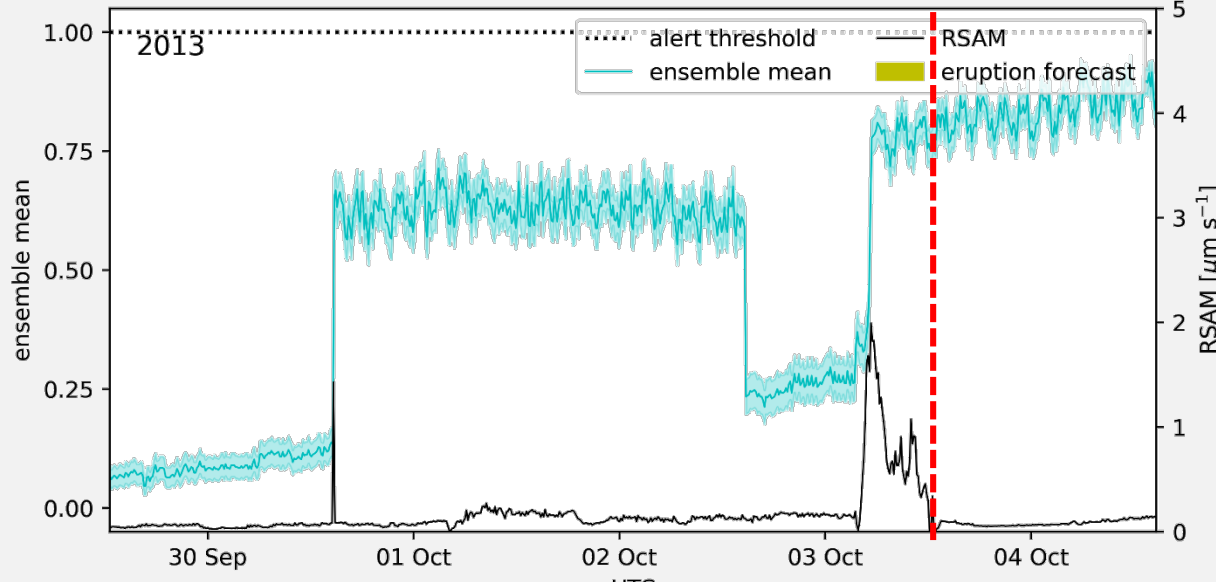
*original forecast
with standardized data...*



Models trained on standardized signals perform about as well on the out-of-sample eruptions used for testing.



original forecast
with standardized data...
...and regional EQs removed



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Standardise and merge data records for different volcanoes. Naively train and test forecast models.



Whakaari

- 10 years of standardized RSAM data
- Five eruptions (2012, 2x '13, '16, '19)
- 7300 windows, 20 pre-eruption

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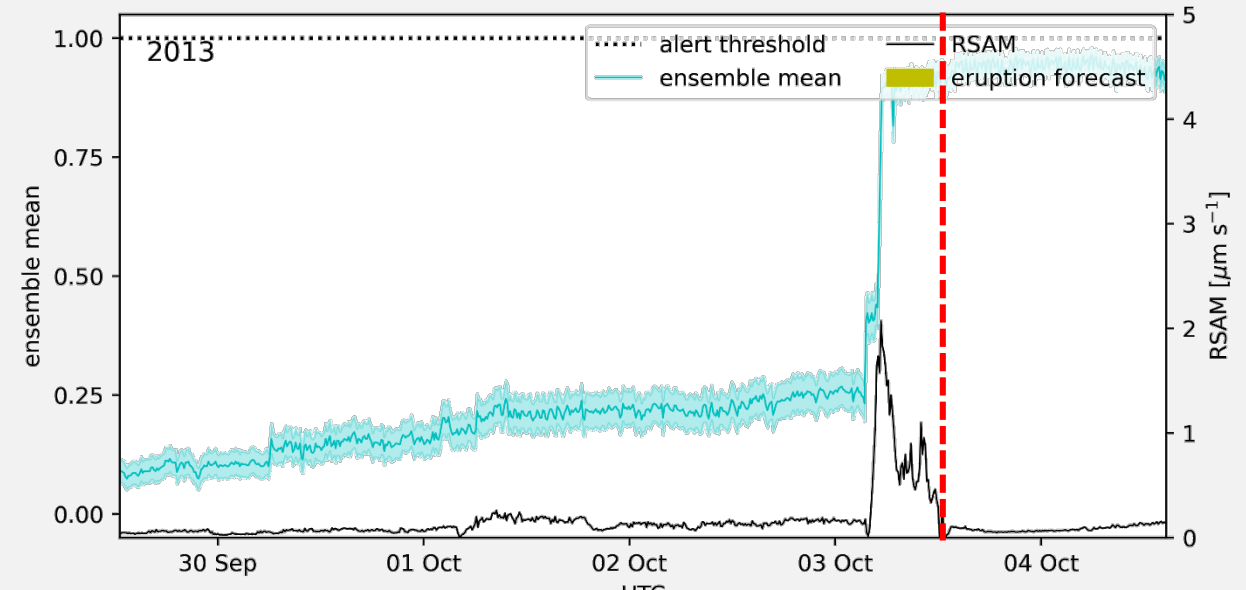
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TRAIN



TEST



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- Two eruptions (2006, 2007)
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TRAIN



~~TEST~~

Standardise and merge data records for different volcanoes. Naively train and test forecast models.



Whakaari-Ruapehu

- 25 years of standardized RSAM data
- Seven eruptions (2006, '07, '12, 2x'13, '16, '19)
- 19 000 windows, 28 pre-eruption

Standardise and merge data records for different volcanoes. Naively train and test forecast models.



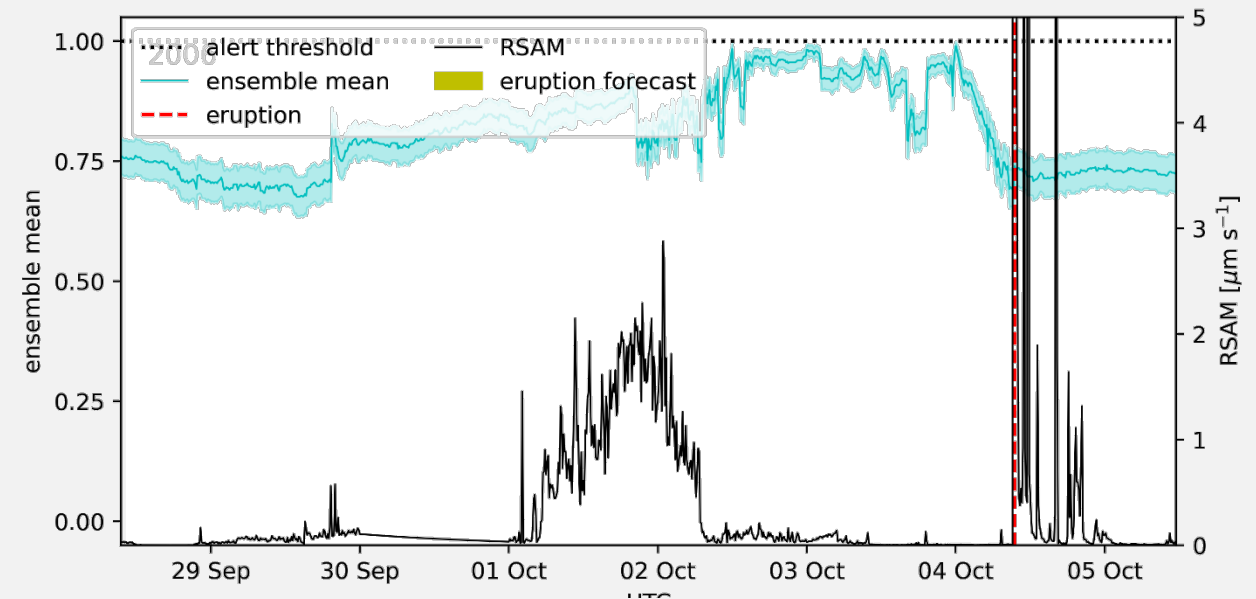
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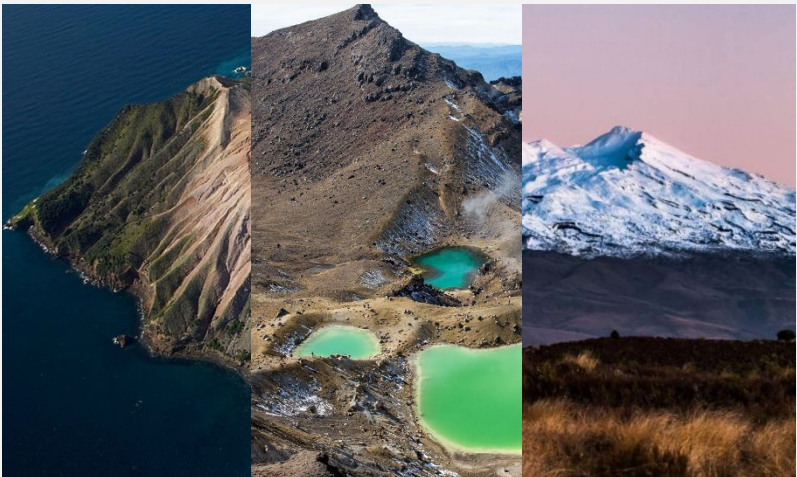


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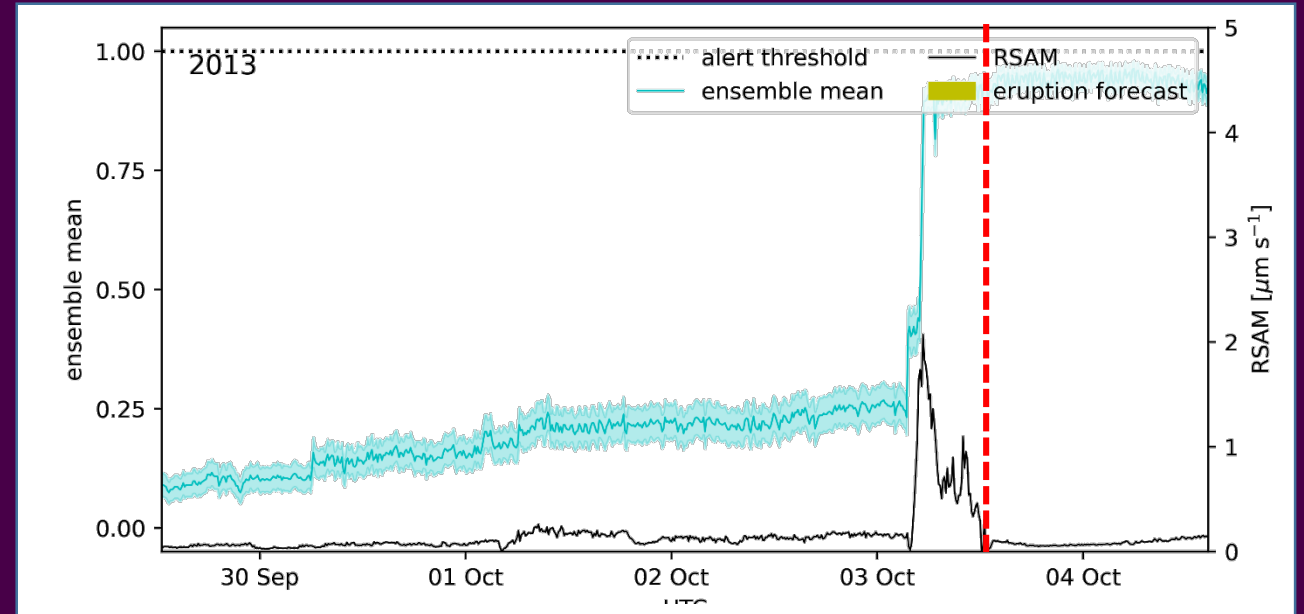
Whakaari-Ruapehu-Tongariro

- 40 years of standardized RSAM data
- Nine eruptions (2006, '07, 3x'12, 2x'13, '16, '19)
- 29 000 windows, 36 pre-eruption

(coming soon)

We are addressing the “not enough data” problem in forecasting, using:

- feature interpolation to fill in network gaps,
- data standardization,
- transfer-learning for multi-volcano models.



Thanks for watching.

More details in:

Dempsey, D. E., S. J. Cronin, S. Mei, and A. W. Kempa-Liehr. "Automatic precursor recognition and real-time forecasting of sudden explosive volcanic eruptions at Whakaari, New Zealand." *Nature communications* 11, no. 1 (2020): 1-8.